IPWEA STATE CONFERENCE 2016 FREMANTLE 9-11 MARCH 2016

"HOW MANY HOLES DOES ONE SOAKWELL NEED?"

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Abstract

Most drainage networks in Perth have multiple soakwells for stormwater infiltration in both private and public land. The humble soakwell has served local government and private householders well over many years, rarely requiring maintenance and continuing to function close to design specification over many years. The original design drawings or testing, specifying the required size of holes in the base and sides to allow water to pass from the inside of the soakwell through to the soil outside, have long been lost or forgotten.

Stormwater Infiltration Testing (SIT) was performed on a 1200 × 1200 mm concrete soakwell at a development site in the City of Armadale during September and October 2015, with high water table, and used a water tanker rather than rainfall runoff for the water source.

This empirical testing of a soakwell is the first to have been documented, so far as the authors are aware. A new, West Australian developed infiltration device "Tunnelwell®" (Tunnelwell) was also subjected to infiltration testing and results are included in this paper.

The tests show high infiltration rates into the underlying sand. These would equate to high continuing losses from rainfall, which would consequently reduce the volume of rainfall that becomes stormwater runoff.

It is hoped that these results will be incorporated in future stormwater manuals produced by metropolitan local authorities.

1. What are soakwells?

A soakwell is a vertical cylinder with base and side holes, usually made from concrete but in some cases from plastic that collects stormwater and infiltrates it into the ground. They are extensively used in Western Australia, where the sandy soils allow for water to be infiltrated 'at source' into the groundwater table.

Soakwells in West Australia (WA) are installed both on housing lots, commercial and industrial estates, and in road reserves.

2. What is Tunnelwell?

Tunnelwell is a WA designed and built stormwater infiltration device. It has optimized sidewall opening (louvres) which prevent sand washing in, and precludes the need for geotextile wrapping which may get clogged over time. Tunnelwell can be laid directly on sand without a base, thus increasing the area available for infiltration.

3. Infiltration testing

An experiment was set up on a sand-filled vacant commercial lot at Harrisdale Green, City of Armadale (Figure 1) to assess the ability of soakwells and Tunnelwell to infiltrate stormwater.

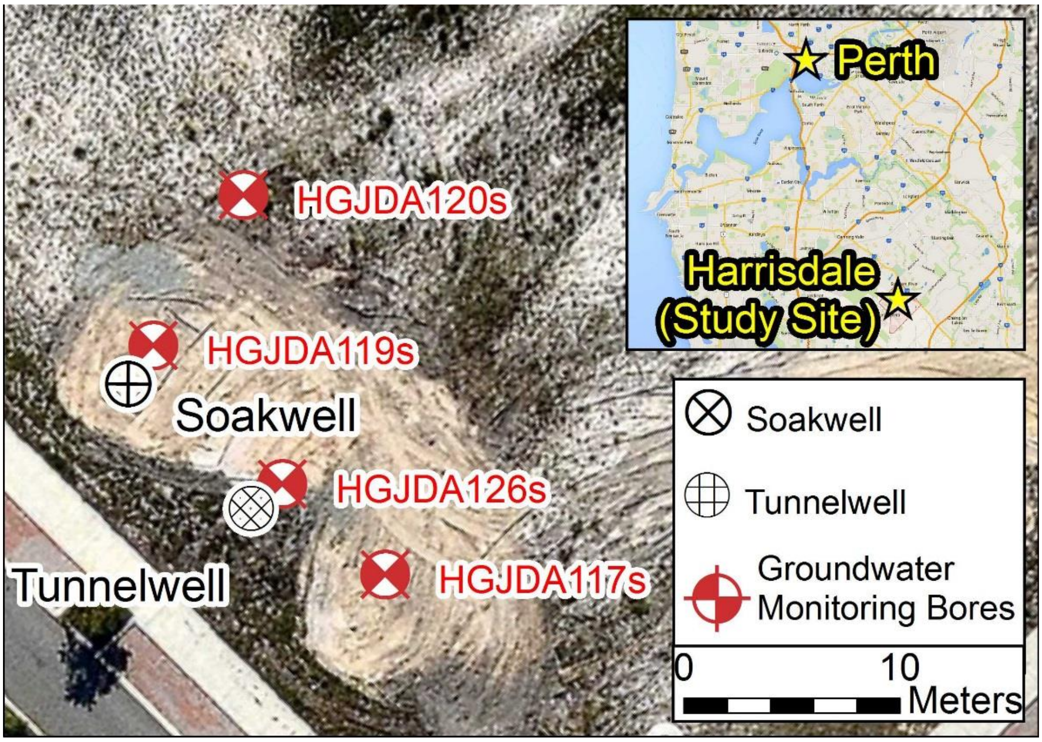


Figure 1: Experimental layout of soakwell, Tunnellwell and monitoring bores.

No such testing appears to have been reported previously, and we are not aware of any data on infiltration rates from soakwells. Infiltration rate depends on soil hydraulic conductivity, interaction with groundwater, as well as on geometry and open areas of the infiltration device. Infiltration is a mirror image of groundwater abstraction, and similar saturated flow equations apply. This experiment is thought to be the first of its kind to collect real data on the performance of infiltration devices.

Tunnelwell is a new product and was tested to see how it compares with a conventional soakwell.

Runoff coefficients for housing lots in similar settings can be derived from these results to assist in sizing of stormwater detention and retention basins.

4. Experimental Setup

The site has sandy soil of approximately 2.5 m thickness over poorly permeable cemented sand (“coffee rock”).

The experiments were performed during September to November 2015 with water from tanker applied at a uniform rate. The water table varied between the seasonal maximum of 1.16 m below ground level in September, to 1.46 m below ground level in November 2015.

A 1200 × 1200 mm (diameter × depth) soakwell, volume 1.4 m^3, was installed in September 2015, see Plates 1 & 2, together with 2 shallow groundwater monitoring bores at varying distances from the soakwell, see Figure 1 and Plates 1 & 2. This allowed monitoring of the water table mound as water in the soakwell infiltrated into the soil.

Plates 1 & 2: Soakwell on concrete base lowered into excavated hole and wrapped in geotextile fabric, then backfilled to surface.

The first test SIT 1 (15/09/15) was run with no blockages of the soakwell, allowing water to infiltrate through both the slots in the sides and the 0.2 m diameter hole in the bottom.

A second test SIT 2 (12/10/15) was conducted with the hole in the concrete base of the soakwell completely blocked (simulating clogging by foreign objects) so water could only flow out via the slots in the side of soakwell.

A third test SIT 3 (23/11/15) was run with a 1.0 m^2 volume Tunnelwell infiltration device, with blank end caps, giving total volume of 1.4 m^3, the same void capacity as the 1200 x 1200 mm soakwell, see Plates 3 & 4. Two additional monitoring bores were installed to monitor the groundwater mound.

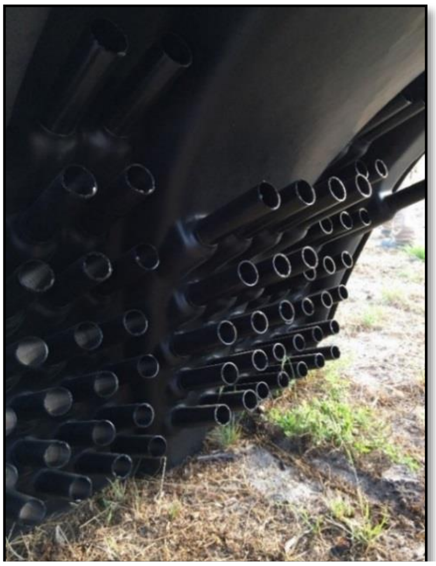


Plate 3: Inside view of the Tunnelwell arch

Plate 4: Tunnelwell in pit ready for backfilling.

In each test SIT 1 to SIT 3, a volume of 15 kL of water from a tanker was discharged into the soakwell and Tunnelwell at a constant rate (1 L/s), rather than simulating a specific storm temporal pattern. Figure 2 shows an IFD graph with the simulated "storm" superimposed showing that the storm ARI increased with duration through the experiment from less than 1 year ARI at 0.1 hours, to greater than 100 year ARI at durations greater than 2 hours.

A typical WA local authority criterion is that soakwells should be sized for 13 mm initial loss. The soakwell and Tunnelwell volume of 1.4 m^3 corresponds to 1.4/0.013 = 105 m^2 impervious area. The total storm runoff volume (15 m^3/105 m^2) = 143 mm.

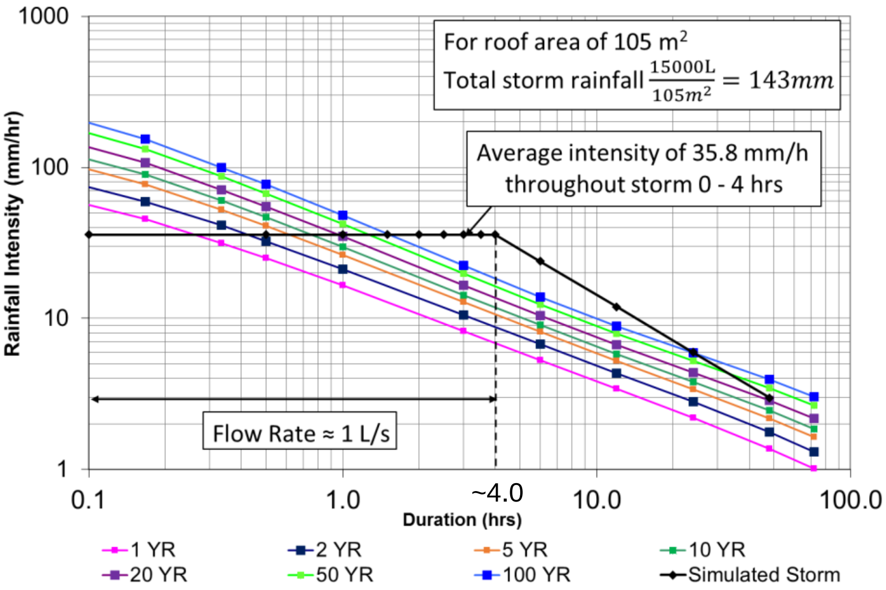


Figure 2: Simulated "storm" (SIT 1 – SIT 3) superimposed on IFD graph.

5. Results

In SIT 1-3, 15 kL of water was discharged into the soakwell and Tunnelwell over 4-5 hrs, with both completely filling with water after 1-2 hours in all scenarios. Water that overflowed infiltrated into the adjacent sandy soil.

Figure 3 shows groundwater levels at bores 2 m away from the soakwell and Tunnelwell. All tests showed a similar temporary rise in the local groundwater level followed by a subsequent fall in groundwater levels after the "storm" ended, with water levels on 15 September 2015 (SIT 1) higher than SIT 2 due to a higher initial water table. Though the Tunnelwell test (SIT 3) had the lowest initial water table, it had the highest peak water level, indicating greater infiltration through side wall louvres.

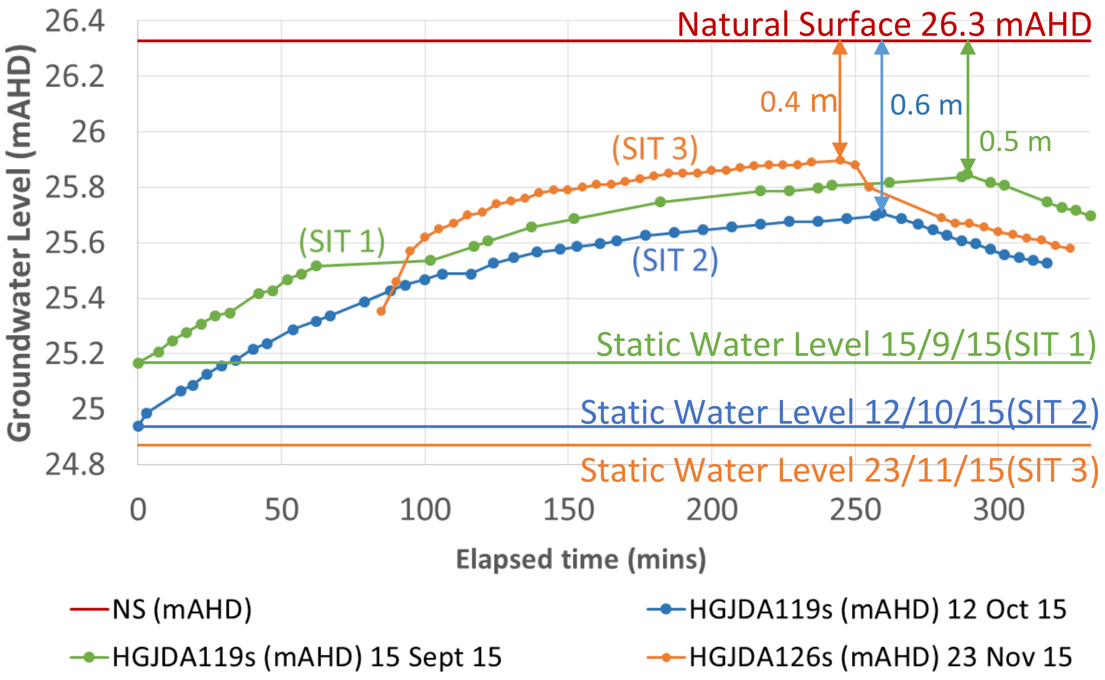


Figure 3: Time series of groundwater levels in monitoring bore 2m way from infiltration experiment.

6. Development of recharge cones

As the tests progressed, cones of wetted soil developed, eventually reaching a steady state.

Aquifer transmissivity (T) above the coffee rock layer was estimated from a Theis Equation analysis as 26 m^2/d, corresponding to hydraulic conductivity (K) of 12 m/d and saturated thickness (D) of 2.2 m.

Figure 4 shows cross sections of the soakwell and Tunnelwell and the corresponding recharge cones.

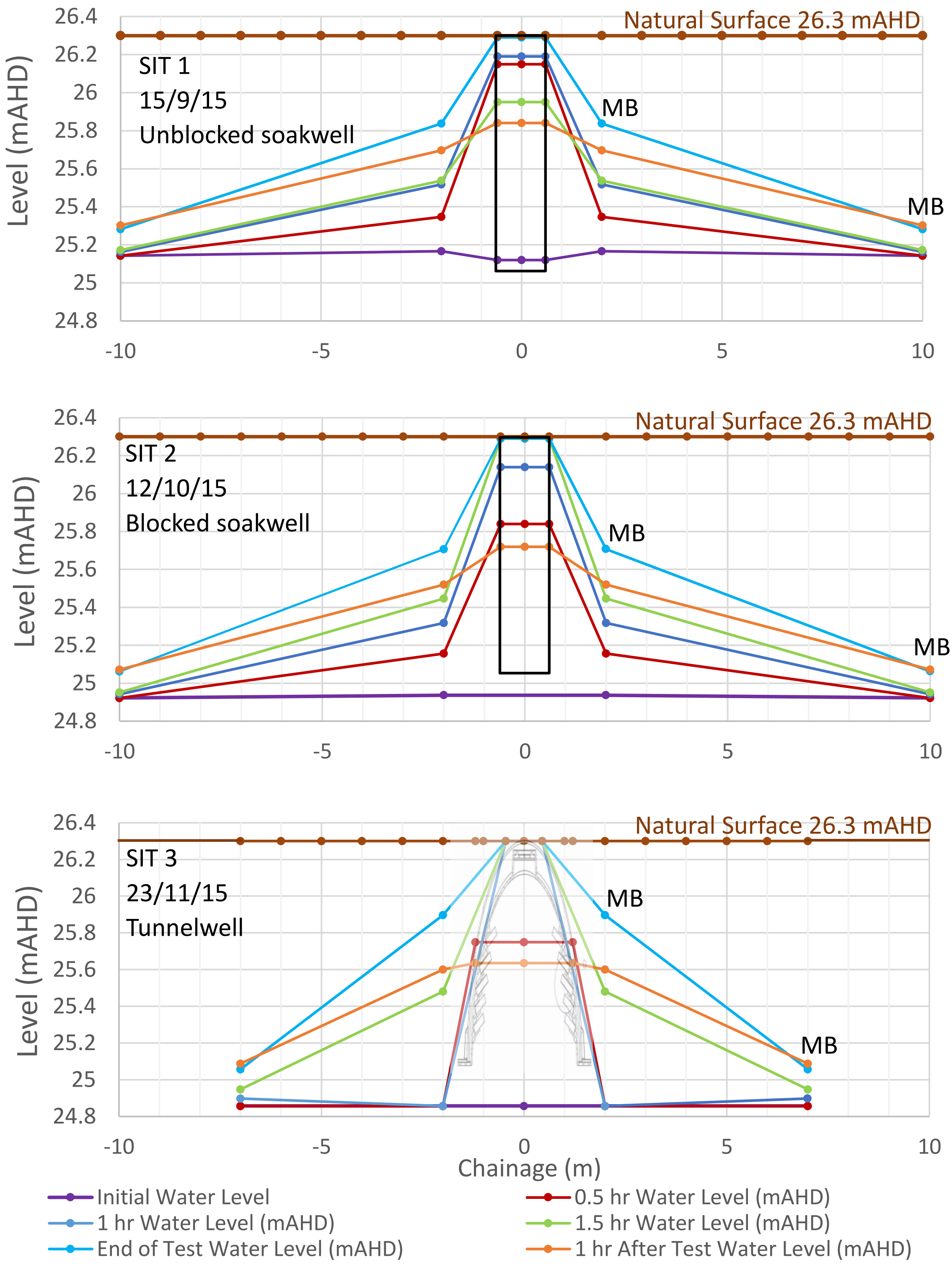


Figure 4 Cross sections of unblocked soakwell SIT 1 (top), blocked soakwell SIT 2 (middle) and Tunnelwell SIT 3 (bottom). MB = monitor bore.

7. Effect of holes in Soakwell and Tunnelwell

7.1 Soakwells

The soakwell has holes both in the sidewall (slots) and base as follows:

(i) Sidewall slots
Number = 18
Size (L × H) = 145 mm × 45 mm
Each slot area = 0.0065 m^2
Total sidewall slot area = 0.12 m^2
Total sidewall area = 4.52 m^2
% slots of total sidewall area = 0.12/4.52 = 2.6%

(ii) Base hole area
Number = 1
Diameter = 0.2 m
Area = 0.031 m^2
Base area = 1.13 m^2
% holes of base area = 0.03/1.13 = 2.8%

(iii) Sidewall slots + basehole
Total open area = 0.12 + 0.031 = 0.15 m^2

7.2 Tunnelwell

The Tunnelwell has louvres in the side walls, with solid end caps. The base of the Tunnelwell is completely open with the arch laid directly onto the sand.

(i) Sidewall louvres
Number = 126
Diameter = 39 mm
Each louvre area = 0.0012 m^2
Total sidewall louvres area = 0.15 m^2

(ii) Base open area
Size (L × H) = 1165 mm × 1312.5 mm
Base open area = 1.53 m^2
% hole of base area = 1.53/1.53 =100%

(iii) Sidewall louvres and base hole area
Total open area = 0.15 + 1.53 = 1.68 m^2

7.3 Discussion

As with boreholes for groundwater abstraction, the greater the open area of a slotted screen, the lower velocity of water flow through the slots, and the lower head required for water to pass from the outside to the inside of the screen. This head is called "well loss", and it is desirable to minimize it, by maximizing the screen open area.

Similarly with infiltration devices, it is desirable to maximize the open area.

The Tunnelwell has larger open area than the equivalent soakwell. The open area of both was adequate and resulted in minimal head loss between the inside and the outside of the infiltration device. However the Tunnelwell with greater open area is superior, especially if clogging is likely to occur over time.

To answer the cryptic question posed by the paper title "How many holes does one soakwell need?" – the results show that the multiple small holes and base hole in both soakwell and Tunnelwell are adequate, so that increasing the number or size of holes would not increase infiltration rate.

In summary both soakwell and Tunnelwell have sufficient open area.

It is the hydraulic conductivity and the water table which limit the infiltration rate, rather than the size or number of openings of the soakwell and Tunnelwell.

8. Stormwater Runoff Estimation

The infiltration results are consistent with previous testing by JDA at a housing lot scale of soakwells (JDA, 2015), which shows zero runoff occurred in a 10 year ARI 12 hour duration storm applied using water tanker. This report is available from the authors on request.

The infiltration testing results in this paper again indicate that lot runoff coefficients are close to zero for storm events on lots with soakwells.

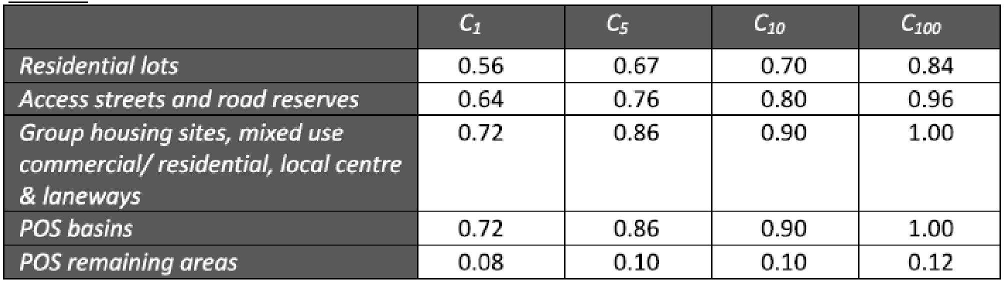
Alternatively, this finding can be stated as the initial loss (IL) is equal to the infiltration device volume of 13 mm and continuing loss (CL) is 32.5 mm/hr.

The rate of continuing loss (CL) for different water table depths and soil hydraulic conductivity values can be estimated using groundwater flow equations in models such as MODFLOW and FEFLOW.

In City of Armadale (2015) fraction imperviousness is suggested as the basis for estimating runoff rates using a 10 ARI Rational Method runoff coefficient based on fraction imperviousness, see Table 3 below and Figure 2 reproduced from City of Armadale (2015). City of Armadale (2015) states that this method is intended as a robust solution which is easy to apply for small scale projects. The publication also states that the Rational Method and Table 3 is not encouraged for most sub-divisions and should be considered for simple applications only. Whilst these may be appropriate for eastern states stormwater runoff estimation, this paper argues that they are overly conservative when water sensitive urban design infiltration practices such as soakwells and Tunnelwell devices are used as is common on the coastal plain around Perth.

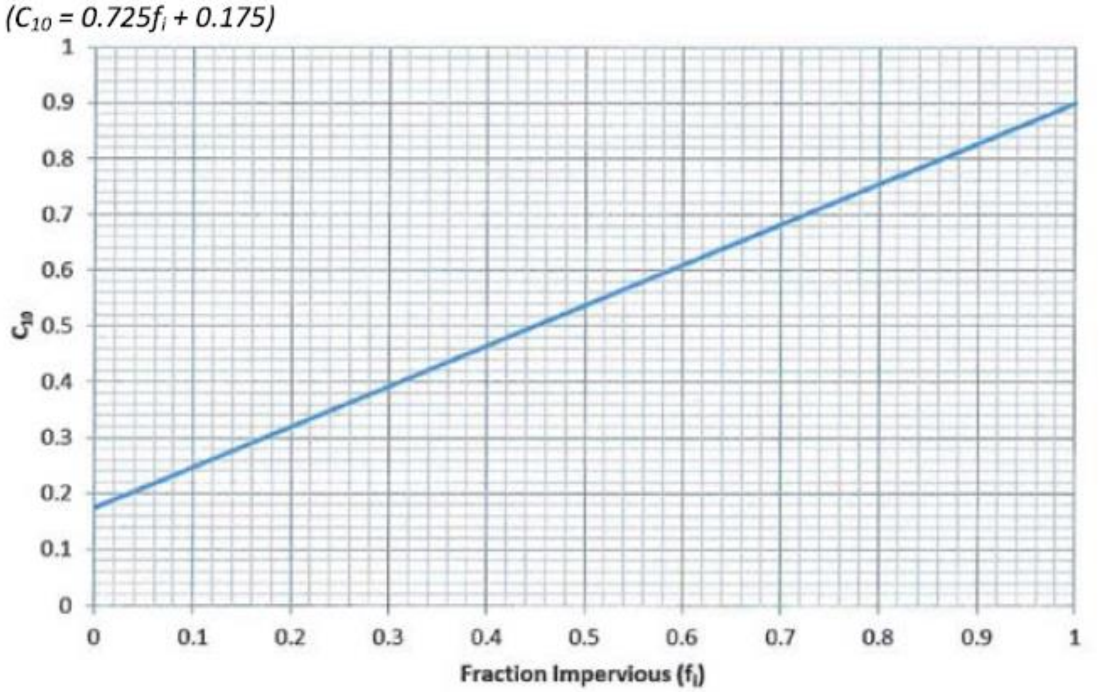
The infiltration testing results reported in this paper confirm that the use of impervious area as a parameter for estimating stormwater runoff rates in Perth on sandy soils may result in gross overestimation.

Table 3



	C_1	C_5	C_{10}	C_{100}
Residential lots	0.56	0.67	0.70	0.84
Access streets and road reserves	0.64	0.76	0.80	0.96
Group housing sites, mixed use commercial/ residential, local centre & laneways	0.72	0.86	0.90	1.00
POS basins	0.72	0.86	0.90	1.00
POS remaining areas	0.08	0.10	0.10	0.12

Figure 2 – Calculating C_{10} from Fraction Impervious



($C_{10} = 0.725f_i + 0.175$)

A subsequent publication prepared for the City of Armadale (Essential Environmental, 2015) contains the following relevant paragraphs:

"The fraction impervious is useful for developing an understanding of the runoff that is likely to be generated by each land use, how this runoff behaves thereafter and how much of it enters a waterway or drainage system must be the subject of site specific analysis. Furthermore the way that this is represented as a 'runoff parameter' will depend on the modelling approach used.

For example, a mid-sized urban residential lot on clayey soils with an FI of 6% may be considered to contribute as much as 80% runoff with very small initial losses where it is provided with a direct connection and no soakwells or other on-site retention system. Conversely, if the lot is sandy, provided with soakwells and has no piped connection it may contribute far less at around 40% to account for continuous infiltration from the soakwell and have a higher initial loss to account for its volume."

The authors support the logic of these paragraphs and reiterate the need for actual data, such as reported in this paper, to be referred to when estimating runoff rates from sites with soakwells.

9. Summary

With a shallow water table, the soakwell and Tunnelwell infiltration devices, both with void capacity 1.4 m^3, infiltrated 15 kL (15 m^3) of water applied from a tanker in a 4 hour period.

The number and size of holes is adequate for both soakwell and Tunnelwell, and increasing the number or size of holes would not enhance infiltration rate.

Assuming designed to hold 13 mm from an impervious catchment area, the void volume of 1.4 m^3 corresponds to an impervious catchment area of 1.4 m^3 divided by 13 mm equals 105 m^2.

The difference between the applied volume (15 m^3) and the void volume (1.4 m^3) is 13.6 m^3, and this volume infiltrated in a 4 hr period corresponding to 13.6 m^3 divided by 4 hour equals 3.4 m^3/hr, or 3.4 m^3/hr divided by 105 m^2 equals 32.5 mm/hr from the impervious catchment area.

These results can be expressed as an initial catchment loss (IL) of 13 mm, followed by a continuing loss (CL) of approximately 32.5 mm/hr.

The continuing loss of 32.5 mm/hr is equal to an infiltration rate of 3.4 m^3/hr divided by 1.14 m^2 equals 3.0 m/hr, or 72 m/d, over the base area (1.14 m^2) of the soakwell. This infiltration rate of 72 m/d is six times the soil hydraulic conductivity (K) of 12 m/d.

Similarly the continuing loss of 32.5 mm/hr is equal to an infiltration rate of 3.4 m^3/hr divided by 1.94 m^2 equals 1.75 m/hr or 42 m/d over the base area of the Tunnelwell of 1.94 m^2. This infiltration rate of 42 m/d is 3.5 times the soil hydraulic conductivity (K value) of 12 m/d.

A more realistic interpretation of the infiltration rate would use the full surface area of the soakwell, including both sides and base area which total 4.52 m^2 plus 1.14 m^2 equals 5.66 m^2 (see Section 7.1).

The infiltration rate calculated using this flow area is 3.4 m^3/hr divided by 5.66 m^2 equals 0.6 m/hr or 14 m/d, which approximates the K value of 12 m/d.

An infiltration rate similar to K indicates a hydraulic gradient close to 1.0, as K is defined at unit hydraulic gradient.

In reality the hydraulic gradient in the recharge cone gradually decreases from a maximum value around the soakwell itself, to much lower values several meters away from the soakwell. At all locations the governing groundwater flow equation (Darcy's Law) is satisfied such that flow rate equals K times hydraulic gradient times flow area.

Using these results, continuing loss rates (CL) for different depths to water table and hydraulic conductivity can be calculated using groundwater flow equations in models such as MODFLOW and FEFLOW.

This data could be used by local authorities as a guide to likely runoff rates on sites with infiltration devices such as soakwells and Tunnelwell.

10.References

JDA Consultant Hydrologists (2015) *Rivergums, Baldivis: Rainfall Runoff Testing.* Report to Cedar Woods Properties Ltd (Ref: J5925b 30 January 2015).

Essential Environmental (2015) *City of Armadale water resource management for land development: A position paper.* December 2015. Prepared for the City of Armadale.

City of Armadale (2015) *Stormwater Management Handbook.*

11.Acknowledgements

Cedar Woods Properties Ltd for funding the soakwell testing described in this pager; Cossill & Webley Consulting Engineers for their logistical and design input; Sentry Holdings Pty Ltd (Tunnelwell) for the Tunnelwell testing.